SOILS AND SOIL BIOLOGY

Panel Manager - Dr. Elizabeth Guertal, Auburn University
Program Director - Dr. Nancy Cavallaro

The Soils and Soil Biology Program supports research that will further our understanding of the basic mechanisms contributing to the immense diversity in soil chemical, physical and biological characteristics in both managed and unmanaged soils and sediments. The program was developed in recognition that soils provide the interface between the biotic and abiotic components of terrestrial ecosystems. It is in the soil that many of the essentials for the production of biomass are obtained and here that nutrients from decaying biomass are recycled into usable forms.

2001-01278 Dwarf Mistletoe Effects on Pine and Pine/Spruce EM Communities Across Soil Types

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Grant 2001-35107-11010; $262,000; 3 Years

Dwarf mistletoe (genus Arceuthobium) is a holo-parasitic plant that acts as a carbon sink, and that can cause up to 75% defoliation of its host. This forest disease remains the most widespread and frequently observed pathogen within the Intermountain Region, and annual losses caused by dwarf mistletoes have been estimated at 3 billion board feet in the western United States. We propose to use molecular-genetic methods to determine effects of dwarf mistletoe infection of *Pinus contorta* (lodgepole pine) in ectomycorrhizal (EM) communities in pure *P. contorta* and mixed *P. contorta/Picea engelmannii* (Engelmann spruce) stands. We will do so across a soil fertility gradient created by a transition from relatively nutrient-rich andesite to nutrient-poor rhyolite. Studies of interactions among plants, microbes, and the soils they inhabit are critical to our understanding of ecosystem function, and hence our ability to successfully manage forested wildlands. We will be the first to investigate alteration of carbon flow to roots and the effect this has on EM communities in a mixed tree species forest, and the first to combine these factors with soil fertility and plant pathogen infection. Using molecular methods, we will provide a more comprehensive picture of this aspect of ecosystem function than was previously possible without them. We will conduct this study in Yellowstone National Park, the centerpiece of the 11-million acre Greater Yellowstone Ecosystem, which includes several National Forests in three states. Thus, we will add greatly to our understanding of a pristine, economically important, and geographically dominant ecosystem.

2001-01217 Effects of Logging and Prescribed Burning on the Ectomycorrhizal Fungal Community Associated with *Abies concolor*

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Grant 2001-35107-11127; $267,000; 3 Years

This work is focused on understanding the effect of prescribed burning and mechanical thinning on the species composition of mycorrhizal fungi in white fir dominated forest. It is directly coupled with a larger experiment conducted by the Forest Service on the effects of burning and thinning. The work is important because mechanical thinning is being considered as a surrogate for prescribed burning to reduce fire hazard and to maintain stand health and structure. Mycorrhizal fungi are root mutualists that are necessary for growth and survival of white fir and all other species in the pine family, yet little is currently known about how they respond to these types of treatments. We will test six specific hypotheses that relate to the effects of fire and thinning on the mycorrhizal community. Results will provide a large-scale detailed picture of the effects of thinning and burning on the mycorrhizal community, and they will yield the first data on the mycorrhizal community associated with white fir. The direct coupling of this work with the Forest Service study at the Teakettle experimental forest means that the results will contribute to larger picture of how fire and thinning effect community composition and ecosystem function. This is a pivotal management question; given the long history of fire suppression and the proposals to reduce fire danger though a combination of logging and fire. In addition, the results will provide base-line data for an important forest type.

2001-01320 Microbial Community Structure in Relation to Organic and Conventionally Farmed Desert Soils

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Grant 2001-35107-11263; $250,000; 3 Years

Desert farms in the southwestern U.S. currently produce millions of dollars of high value crops, but rely heavily on the use of inorganic fertilizers and pesticides. Several growers in the low desert are interested in converting to organic farming practices to meet the demand for organic produce and to improve soil quality and sustainability. Organic and low input fuming methods are known to alter basic soil biological process, and change the structure of soil microbial communities; however, there is still no mechanistic understanding of the relationship between microbial communities, microbial diversity, and basic ecosystems processes such as organic matter degradation and nutrient cycling. Research proposed here will examine three hypotheses related to the effects of long term organic inputs on microbial communities. Experiments will examine (1) the effects of organic matter additions on the numbers and diversity of bacterial species that degrade various carbon compounds that are contained in plant residues, (2) the relationship between changes in soil physical structure and bacterial community structure, and (3) the effects of organic matter additions on microbial community structure in the plant rhizosphere. The information provided here will aid in grower decisions on specific management regimes and will provide fundamental information on the linkage between microbial diversity and soil biological processes. The research will also contribute to the advancement of DNA microarray technology for community analyses, which may have extensive applications for future research on soil biology.

2001-01242 Degradation of Acyl-homoserine Lactone Signal Molecules by Soil Microbiota

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New Investigator Award, Grant 2002-35107-11530; $70,600; 2 Years

Acyl-homoserine lactones are naturally occurring compounds produced by dozens of species of so called “quorum sensing” soil bacteria, which produce and use them as signals in the regulation of several important soil processes. Numerous quorum-regulated activities are considered beneficial to plants, while others are clearly involved in plant pathogenesis. Thus, it is important to understand any factors that might impact acyl-HSL-mediated quorum sensing in soils. However, most studies on quorum sensing have been restricted to the use of pure-cultures of bacteria grown under narrowly defined laboratory conditions. Little information is available on the short- or long-term fate of acyl-HSL signals, or on the factors that influence the efficacy of quorum sensing in soils. In this research, aspects of the biodegradation of acyl-homoserine signal molecules by the soil bacterium *Variovorax paradoxus* will be examined. Acyl-HSL degradation is a newly recognized mechanism by which specific soil C and N can be recycled and used as a nutrient. The kinetic and growth parameters for *V. paradoxus* growing at environmentally relevant, low acyl-HSL concentrations will be determined in batch and chemostat cultures. Additionally, the capability of *V. paradoxus* to disrupt acyl-HSL mediated signaling by other soil bacteria will be elucidated in defined co-culture

2001-01235 Effect of Colloids on Virus Survival and Transport in Porous Media

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Standard Strengthening Award, Grant 2001-35107-11142; $315,000; 3 Years

Groundwater contaminated with pathogenic microorganisms has been implicated in more than 70% of all waterborne disease outbreaks in the United States. Sources of groundwater contamination with viruses include septic tanks, private and municipal waste-disposal systems, and land application of sewage sludges and animal wastes. Because viruses can travel long distances in soil and groundwater aquifers and pose a public health threat at a very low level, it is critical to understand all the processes/mechanisms controlling their survival and transport in the subsurface in order to establish regulations that are protective of public health. A potentially important mechanism responsible for virus transport is facilitated by colloids, which has been largely overlooked in previous studies. The main purpose of this proposal is to conduct a comprehensive study to systematically investigate the three major processes that potentially contribute to the importance of colloid-facilitated virus transport: (1) virus association with colloids, (2) virus survival characteristics in the presence of colloids, and (3) co-transport of viruses and colloids under various environmentally relevant conditions. This project integrates experiments at both microscopic (molecular) and macroscopic (batch and column) scales. Information obtained will ultimately lead to prediction of virus transport under a variety of soil and environmental conditions. Because we will use avian pathogens as model viruses, the results are expected to be directly applicable to infer behavior of human pathogenic viruses in the subsurface environments, as well as to provide valuable information on the mobility of viruses via land application of sewage sludges and animal wastes.

2001-01233 Rotation of Pastures with Crops to Achieve Productivity and Environmental Quality

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Grant 2001-35107-11126; $235,000; 3 Years

Soil organic matter is considered an essential foundation for achieving long-term stability and productivity in agricultural ecosystems. Long-term pastures have the potential to sequester a large amount of soil organic carbon. Rotation of grain crops with pasture could be an opportunity for producers to capitalize on the benefits of high soil organic matter, although the management strategies to achieve high productivity and maintain environmental quality are not well known. Our objective is to quantitatively evaluate three management factors (i.e., tillage, time of grain cropping, and cover crop management) for their impacts on plant and animal productivity, soil quality, and fluxes of potential pollutants to the environment. The factorial arrangement of treatments will identify significant interactions among management factors, which should lead to a better understanding of the processes controlling productivity and environmental quality. Tillage variables will include conventional inversion and no tillage. Cropping systems will include summer grain followed by winter cover cropping and winter grain followed by summer cover cropping. Cover crops will be either grazed by cattle or left in the field to produce surface residue cover. We expect the retention of surface residues and high soil organic matter at the soil surface to buffer the impact of grazing animals on soil physical properties, water runoff, soil organic matter changes, and soil biological diversity and activity. We also expect that a small subset of the soil response variables will explain the majority of the variation in plant and animal productivity and environmental health.

2001-01202 The Role of Mimosine and Mimosine-degradomg Bacteria in the Leucaena Rhizosphere

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Grant 2002-35107-11659; $159,350; 2 Years

The organic material released from plants as root exudates provides a continuous source of nutrients to many microorganisms living in the root zone or rhizosphere of plants. Many of the compounds in the root exudates serve as nutrients for rhizosphere bacteria. We found that mimosine, a toxic nonprotein amino acid present in the root exudates of leucaena (*Leucaena leucocephala*) is used as a source of nutrients by some strains of *Rhizobium*. Mimosine has a strong affinity to bind with iron and therefore it may play an important role in maintaining availability of soluble iron in the leucaena rhizosphere. Leucaena grows relatively well in dry and nutrient-deficient soils where other plants usually cannot grow or survive. We propose here that mimosine released by leucaena in the root exudates serves as a mechanism to sequester iron and other cations. Mimosine forms an iron-mimosine complex, which is taken up by mimosine-degrading bacteria such as *Rhizobium* and *Klebsiella* in the rhizosphere. We have identified and sequenced several genes required for mimosine degradation by *Rhizobium*. We hypothesize that bacteria such as *Rhizobium* and *Klebsiella* utilize iron-mimosine complex and release solubilized iron for the leucaena plant. This research will investigate a novel mechanism for iron uptake in leucaena and the role of mimosine-degrading bacteria in the rhizosphere. The results of this investigation will provide fundamental information related nutrient uptake by plants that may enhance agricultural production and promote agroforestry.

2001-01249 Molecular Structure of Inner-sphere and Aqueous Multinuclear Pb(II) and Cu(II) Complexes on Clay Minerals

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New Investigator/Standard Strengthening Award, Grant 2001-35107-11261; $176,000; 3 Years

This project involves basic research directed toward determining the molecular structure of metals on clay mineral surfaces. Clay minerals are important constituents of soils since they control the availability of nutrient and contaminant cations for uptake by microorganisms, plants, and animals. In specific, clay minerals are able to retain or release nutrients and/or contaminants (e.g., copper, lead, magnesium, and cesium) into soil solution via sorption and desorption reactions. Thus, to effectively manage nutrients and contaminants in soils it is critical that the reaction mechanisms occurring between metals and clay minerals are understood.

Traditionally sorption on clay minerals was considered to be an electrical attraction between the positively charged cations and the negatively charged surface. However, recent research has provided evidence that other sorption reaction mechanisms are also occurring, including, complexes that involve shared electrons between the cations and the clay minerals, and clusters of cations on the mineral surfaces (multinuclear complexes). The formation of multinuclear complexes has been shown to occur when speciation models predict they should not be occurring. This suggests that the clay minerals are enhancing the formation of these complexes.

The goal of this project is to use advanced analytical techniques and clay minerals with unique sorption site characteristics to investigate lead (Pb) and copper (Cu) sorption mechanisms. The results from this research will provide new information that will be used by soil scientists, geologists, environmental scientists, and engineers to create more accurate models for predicting the fate of nutrients and contaminants in soils.

2001-01203 Enhancing Establishment and Proliferation of Fungal Soil Inocula

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Grant 2001-35107-11008; $171,131; 2 Years

Numerous soil fungi in a number of genera show promise as agents for biological control of soilborne plant pathogens, or for bioremediation of chemical pollutants in soil. However, poor competitive ability of introduced fungal agents in soil communities, leading to unsuccessful establishment and activity, has typically been observed. This severely limits their utility as biological control or bioremediation agents. Our long-term goals are to understand and quantify the factors that determine the establishment and activity of fungi introduced into natural soils, and, then, to develop appropriate technologies to overcome these obstacles and successfully deploy fungal biocontrol and bioremediation agents to soil systems. The objective of this project is to test the hypothesis that temporary reduction of competitive pressure from indigenous microbial communities will enhance survival and proliferation of introduced fungi in soil. As tools to explore this hypothesis, we will use two novel approaches: (1) use of an introduced fungal agent transformed with green fluorescent protein (GFP) to help visualize and measure fungal growth and competitive ability in soil; (2) use of plant residues that produce anti-microbial glucosinolate compounds, to inhibit native soil microbes and establish favorable conditions for the introduced fungal agent.

2001-00651 HPLC Examination of Siderophore Catabolism

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Equipment Grant, Grant 2001-35101-11532; $21,750; 1 Year

Iron is often a limiting micronutrient for plants and the microorganisms that colonize plants. Microbes have evolved highly efficient mechanisms to sequester iron which use the molecules termed siderophores as the agents that obtain the metal. Siderophore sequestration of iron is more efficient in obtaining iron than the mechanisms employed by plants. Plants avoid iron starvation by utilizing the iron available when siderophores are degraded and thus not fully able to sequester iron. As such, those processes which result in siderophore degradation are important to the iron nutrition of plants as they represent the means by which iron is provided to plants.

Our laboratory has isolated a soil bacterium, a *Rhizobium loti* strain, which can degrade the siderophore deferrioxamine B and use it as a nutrient source for growth. This process is termed catabolism. The *Rhizobium loti* will be used to discern the enzyme (biological catalyst) and the biochemical pathway by which the siderophore is degraded. The HPLC equipment of the grant is instrumental in discerning these goals, as it will allow both the isolation of the siderophore degradation products and the enzyme.

The importance of this work to agriculture comes from understanding how siderophores are degraded and thus how the molecules are rendered useful to plants. The study also has the potential of developing microbes and enzymes that would specifically enhance the iron uptake of plants such that agriculturally important species will not be growth limited due to the lack of this essential nutrient.

2001-01257 Dynamics of Soil Manganese and Soilborne Plant Disease

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Grant 2001-35107-11143; $166,291; 2 Years

The soil fungus that causes the "take-all" disease of wheat can somehow convert soluble soil manganese to the insoluble form. This may be an important step in the disease process because manganese is essential for plants and plays key roles in photosynthesis and plant defense against diseases. Plants take up manganese through their roots, but they can only take up the soluble manganese, while the insoluble manganese remains in the soil as various oxide minerals. The balance between soluble and insoluble soil manganese is determined by a complex interaction between soil microorganisms, crop residues, and weather conditions. Field observations show that the take-all disease is more severe after some crops than others. One of our objectives is to determine whether this crop rotation effect is the result of changes in soil manganese availability. A second objective is to determine the biochemical mechanism by which the fungus converts plant-available, soluble manganese to the non-available, insoluble form. Finally, we know that plant roots can produce substances that convert insoluble manganese to soluble forms. Our third objective is to determine the distribution of plant available and unavailable manganese in the vicinity of live plant roots growing in soils using high-energy x-ray beams at the Advanced Photon Source at Argonne National Laboratory. This project will provide information for improving strategies to reduce crop losses due to plant disease, thus contributing to the long-range competitiveness and efficiency of American agriculture.

2001-01318 20th Anniversary Meeting of International Humic Substances Society
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Conference Grant, Grant 2002-35107-11639; $7,140; 1 Year

Humic substances (HSs) are the brown biomaterials that impart color and affect the properties of soils, sediments and water. These materials are essential for the success of US agriculture. They are the metabolites of lignins, polysaccharides and proteins. HSs results from microbial action in a process called humification, which is catalyzed by water containing metal ions, particularly of copper and iron, and by iron and manganese minerals. They also exist in animals, biowastes, soft coals and plants. HSs have been studied for more than 200 years and major progress in understanding them has been made in the last 1-2 decades. Great credit for this progress belongs to the International Humic Substances Society, which was founded in 1982, incorporated in Colorado in 1983 and is the only recognized source of reference and standard HSs samples for comparison with locally isolated materials. In 2002, the IHSS Conference returns to the US for the first time in 20 years. We will celebrate 20 years of progress in understanding and applying the remarkable materials called humic substances with a first-class meeting. This proposal requests $7140 in financial support from the Soils and Soil Biology Program of CSREES/NRI for participation of six eminent invited US scientists at the 20th Anniversary Conference of the International Humic Substances Society to be held at Northeastern University, Boston, Massachusetts from July 21-26, 2002. Each author will be requested to acknowledge support from CSREES/NRI in his/her presentation and in any publications resulting from the presentation and related work.

2001-01277 The Impact of CO2 fertilization on Soil Carbon Storage Below a Forest
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Grant 2001-35107-11242; $125,000; 2 Years

The aim of this research is to determine the amount of carbon being transferred from the atmosphere to the soil because of CO2 fertilization. CO2 fertilization is the increase in plant growth in response to elevated atmospheric carbon dioxide levels. Increased plant growth may lead in increased soil carbon storage. Knowing how much additional carbon is stored in soil because of CO2 fertilization will lead to more accurate predictions of future CO2 levels and global warming. To see if CO2 enrichment increases soil carbon storage, I have collected a set of unique samples and developed a method for determining the soil carbon CO2 fertilization factor using radiocarbon, d13C, and carbon inventory measurements. The soil carbon CO2 fertilization factor is the fractional change in soil carbon input divided by the fractional change in carbon dioxide level. It is my hope that the techniques used for this research will be applied to other CO2 fertilization experiments and used to evaluate how much carbon might be sequestered in soil by re-vegetating abandoned agricultural land. If a type of vegetation had an unusually high soil carbon CO2 fertilization factor, plantations of this species could be established on abandoned cultivated land to further slow the build-up of atmospheric carbon dioxide levels. To date, the soil carbon CO2 fertilization factor has been determined for only one CO2 enrichment experiment.

2001-01289 Iron Redox Reactions with Natural and Synthetic Chemicals in the Rhizosphere

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Grant 2002-35107-11572; $175,000; 3 Years

This work examines the chemical reactions of iron in the water and soil next to plant roots, a microenvironment termed the rhizosphere. Iron is a key plant nutrient, and the principal redox-active element in soils. The higher oxidation state of iron, Fe(III), is capable of oxidizing a number of important agricultural chemicals and forms soil minerals that adsorb toxic metal ions such as nickel and zinc. In some instances, bacteria can use Fe(III) instead of oxygen for driving metabolic processes. The lower oxidation state of iron, Fe(II), is capable of reducing a wide range of inorganic and organic chemicals. Grass roots acquire iron as Fe(III), while most other land plants acquire iron as Fe(II). Plants roots, as well as nearby bacteria and fungi, release biological chemicals that control the oxidation state of iron in soils. The identity of these biological chemicals, and the ways in which they react with soil iron, are poorly understood. Our work explores pathways and determines rates of Fe(II) oxidation and Fe(III) reduction under rhizosphere conditions. Through this work, we hope to establish how plants and other organisms control the oxidation state of iron. Analytical methods include HPLC (High Performance Liquid Chromatography), and a new sensitive and selective technique, CE (Capillary Electrophoresis.) Results from this work may assist agricultural scientists in such areas as matching crops with soils possessing suitable chemical properties, extending the geographical range of important crops, lessening flood damage, optimizing the effects of agricultural chemicals, and mitigating the effects of soil pollutants.

2001-01193 Response of Fine Root Chemistry to Elevated CO_2 and O_3: Implications for Soil Carbon Cycling and Storage

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Grant 2001-35107-11262; $265,000; 3 Years

Human society depends on forest ecosystems to provide the many wood products and ecological services that support our quality of life. However, our activities are changing the atmosphere in ways that will directly affect the capacity of forests to provide a sustainable supply of goods and services. Atmospheric concentrations of carbon dioxide (CO_2) and tropospheric ozone (O_3) are rising at historically unprecedented rates. Carbon dioxide acts as a fertilizer, increasing rates of photosynthesis and growth, while O_3 is toxic to plants, having the opposite effect. Since the basic building blocks of plant matter are constructed from the very air we breathe, the changing atmosphere will alter the chemical composition of plant tissue. Changes in plant tissue chemistry are important because they affect the rate and extent to which soil microorganisms can break down plant litter, thereby influencing nutrient availability in soil and future forest productivity. The goal of our research is to determine how the chemistry of fine roots will change in response to the rising levels of CO_2 and O_3 in economically important northern forest types. We will determine how these chemical changes affect the physiology of soil microbial communities, and in turn their capacity to break down plant litter and form soil organic matter. Our research will provide predictive insight on how a changing atmosphere affects the cycling of carbon in forest soils by changing the physiology of plants and soil microorganisms, and what this means for the sustainable supply of wood products from northern forests.

2001-01287 Soil Organic Matter-Driven Selection of Atrazine-Degrading Microbial Populations

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Postdoctoral Fellowship, Grant 2001-35107-11102; $89,981; 2 Years

The impacts of pesticide use on environmental quality are a significant issue influencing the sustainability of agriculture. Soil organic matter (SOM) is considered one of the most important factors responsible for controlling the fate of pesticides in soils and sediments. SOM can restrict contaminant availability to microorganisms leading to the evolution of microbial populations that are specialized at accessing bound contaminants. However, most attempts to isolate contaminant-degraders are done in the presence of excess contaminant. The goal of this project is to assess the influence of SOM on herbicide-degrading microbial populations. The proposed research will address this issue by enriching for atrazine-degrading microbial populations using atrazine that is pre-sorbed to SOM solid phases. These phases will influence the bioavailability of the contaminant and serve as a potential co-substrate for microbial metabolism. Additional enrichments will contain atrazine as a mixture component, as is typical for many pesticide applications. The co-occurring pesticides found in the mixtures have the potential to serve as alternative substrates and/or compounds inhibitory to atrazine degradation. The microbial populations selected under these conditions will be analyzed using molecular techniques and cultivation-based methods. The molecular methods used will target (1) genes that allow the identification of the populations present and (2) functional genes that have been characterized in well-studied atrazine-degrading isolates. By using a combination of novel approaches, progress towards identifying microbial populations responsible for pesticide degradation *in situ* will be gained.

2001-01248 New Thermodielectric Method to Determine Soil Specific Surface Area and Bound Water

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Grant 2001-35107-11009; $275,000; 2 Years

Soil water measurements by electromagnetic methods including time domain reflectometry (TDR) are extensively utilized in agricultural research and management. We recently resolved a substantial temperature influence on TDR-measured soil water contents that also affects other sensors across a wide frequency range. The sometimes, contradictory dielectric behavior of wet soils was explained with a new physical model that considers interplay between competing dielectric responses of bulk and bound soil water to changes in temperature. ‘Bound water’ refers to thin films of water held very tightly to solid surfaces. Thermodielectric sensitivity must be compensated for obtain accurate soil water information, even for a range of remote sensing methods. The preliminary model includes several simplifying assumptions and uncertain parameters that require clarification, and a more explicit treatment of dielectric properties of bound water is needed. We showed that the thermodielectric phenomenon may be exploited to obtain measurements of wettable specific surface area of soils and other porous media. Specific surface area is critical to behavior of soil water and agricultural chemicals, and to myriad soil microbial processes, yet is underutilized due to lack of simple and accurate measurement methods. The study objectives are to enhance the model to more accurately address dielectric responses of bound water leading to development of simple correction factors for water content measurements using TDR, capacitance, and related methods. A new method for noninvasive determination of specific surface area of soils will be refined and authenticated using comprehensive laboratory experiments, leading to more effective use of our agricultural resources.

2001-01246 Management Effects on Phosphorus Cycling in 20-Year-Old Loblolly Pine Plantations on Contrasting Soils

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Grant 2001-35107-11197; $140,000; 3 Years

Loblolly pine is the most important commercial timber species in the United States. Management techniques employed by the forest industry have the capability to at least double current growth rates. Doubling growth rates not only has important economic implications, but also may play a vital role in enhancing terrestrial carbon storage. Managing phosphorus (P) availability is key to achieving and maintaining higher growth rates in loblolly pine plantations. We know little about the long-term effects of management on P availability, because it takes about 20 years to grow a plantation. The main objective of this project is to further our understanding of long-term P availability in plantations. The research will be conducted on the oldest replicated field study in the southeast United States, which was installed in 1980 to determine long-term site and pine growth response to several management techniques. We will conduct detailed analyses of site P pools, as well as determine how the soil environment affects the amount of P made available to plants. The results of this project will increase our understanding of site and management factors that explain the variation in P and also contribute towards our ability to model P availability in pine plantations. Additionally, the knowledge we gain will be important for designing management systems that are economically attractive, environmentally sound, and socially acceptable.

2001-01185 Predicting Contaminant Dehalogenation Rates from Electron Scattering Studies

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Grant 2001-35107-11147; $150,000; 2 Years

Pesticide spills and discharges take place each year on farmsteads and cooperatives. When these events occur normally beneficial chemicals become point sources of contamination for ground and surface water. Although the soil-water environment has an enormous potential to naturally break down pesticides, this capacity is often exceeded when chemicals are disposed in confined areas. To combat these point sources of contamination, treatments are needed that alter the chemistry of the contaminant so that natural biodegradation can proceed. The realization that many pesticides are less stable under low oxygen (reducing) conditions has generated interest in engineering reducing environments in soils, sediments and aquifers for remediation purposes.

Based on this premise, one technology gaining widespread acceptance is the use of metallic metals (zerovalent metals) as chemical reductants. Zerovalent iron is an avid electron donor and when added to soils or ground water a reducing environment is created. Recently, we demonstrated the effectiveness of zerovalent iron to remediate a metolachlor-contaminated soil at a spill site. From a regulatory perspective, the ability to reliably predict degradation rates following treatment with zerovalent iron would be greatly accelerate the use of this emerging technology. The most fundamental way to determine how readily a contaminant can be reduced is by measuring vertical attachment energies through electron scattering studies. This research will conduct numerous electron scattering experiments on a variety of pesticides and chlorinated compounds and use this data to develop a model for predicting degradation rates of contaminants following treatment with zerovalent iron.

2001-01332 Effects and Modes of Action of Vermicomposts on Growth of Field Horticultural Crops

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Grant 2001-35107-11045; $285,800; 2 Years 6 Months

Vermicomposts are produced by interactions between earthworms and microorganisms on the degradation of organic wastes. We have evidence that plant growth-influencing substances, including hormones and humates, may be produced during the vermicomposting process.

Our main objectives are: (1) to analyze comprehensively the major physical, chemical and biological properties of two different sources of vermicomposts produced from cattle waste, food waste and paper waste; (2) to follow temporal changes in the physical, chemical and biological properties of soils in the field after addition of two low rates of application of cattle, food and paper waste-based vermicomposts, or a recommended rate of inorganic fertilizer, to field plots; and (3) to determine the effects of two low rates of field applications of cattle, food and paper waste-based vermicomposts, or a recommended rate of inorganic fertilizer, on the growth, flowering, fruiting and yields of marigolds, peppers, and strawberries.

The three vermicomposts will be applied to replicated field plots at two low application rates and temporal changes in the physical, chemical and biological properties (including plant growth-influencing substances) assessed. The effects of vermicomposts and inorganic fertilizer, balanced for nutrient content, on the growth of marigold, peppers and perennial strawberries will be compared. Growth, nutrient content, time of flowering, fruiting, yields, soil nutrients, disease and pest incidence and nematode trophic levels will be measured. The effects of aqueous extracts of plant hormones, and base extracts of humic acids from vermicomposts, on the growth of the three crops will be assessed in pot experiments.

2001-01208 Hot Spots of Nitrogen Cycling in Soil

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Grant 2001-35107-11044; 275,292; 2 Years

For soil quality and crop productivity to be sustained on U.S. agricultural lands into the foreseeable future, a balance must be struck between mineralization of plant and animal residue inputs as sources of plant nutrients, and sequestration of organic C and N by the soil for maintenance of soil physical qualities. Although it is well known that mineralization and immobilization of N can occur simultaneously in soil, it is not known what soil properties are essential for these activities to coexist. Although we suspect that spatial separation of microbes and their respective N sources is important, we have no information about the scale of spatial separation that is needed. The objectives of our work are to establish at what spatial scale N cycling processes are compartmentalized in soil. In addition, we will locate the activity, and characterize the nature of the microbes involved in mineralization and immobilization of N in soil. We will use a combination of state-of-the art techniques. These include a novel mass spectrometric procedure, which enables us to examine N processing by microorganisms at the micron scale of resolution. We will use molecular and physiological techniques to identify the nature of the microbes involved in assimilating inorganic N in specific locations. From completion of our objectives we will gain a better understanding of the soil conditions, and the nature and location of key microbial species that play crucial roles in coupling the N cycling processes that are essential for maintaining crop productivity and enhancing soil quality.

2001-01197 Qualification and Characterization of Black Carbon in Soil
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Standard Strengthening Award, Grant 2001-35107-11129; $150,000; 3 Years

Soil organic matter (SOM) is the dominant component for binding and attenuation of organic pollutants in soils. Quantification and characterization of SOM are key to predicting fate and to assessing environmental risks of organic pollutants such as pesticides. Previous studies focused on quantifying physical and chemical properties of extractable SOM fractions and their interactions with organic pollutants. The properties of non-extractable SOM fractions remain very unclear although it is believed they are more important for reducing chemical reactivity and hence toxicity of organic pollutants.

This study focuses on quantification and characterization of black carbon in soils and its interaction with pesticides. Black carbon, commonly called charcoal or soot, is formed in combustion processes of fossil fuels or biomass due to incomplete oxidation or condensation of organic fragments. This material can transport from various sources by atmospheric circulation and/or surface water runoffs, and ultimately becomes as a part of non-extractable SOM in topsoils and sediments.

In this study, a chemical procedure will be developed to quantitatively isolate black carbon from soils and sediments. The physical and chemical properties of the isolated black carbon will be characterized. Sorption of selected pesticides by the black carbon materials and their original soil samples will be measured. A correlation between black carbon content and sorption capacities of organic pollutants by soil will be developed. The study will elucidate the role of black carbon in binding and sequestration of pesticides by soil.

2001-00670 Acquisition of a Total Organic Carbon Analyzer
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Equipment Grant, Grant 2002-35100-11680; $24,653; 1 Year

Humin is an insoluble organic matter fraction that usually represents more than 50% of the organic carbon present in a soil. The majority of pesticide residues bound to the soil (i.e., greater than 50%) are bound to this material. For these reasons, understanding the binding phenomena is vital to developing a predictive understanding of the fate and transport of pesticides in the environment. Typically, the processes involved are related to the distribution of the amount of carbon present in the soil, or as each humic material fraction. The instrument requested in this proposal will be used in an ongoing research program to study the nature and formation of humin, and its interaction with bound pesticide residues in soil.

2001-01319 Proteomic Investigation of Energy Starvation and Toxicant Stress Shock in *Nitrosomonas europea*

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Grant 2001-35107-11046; $190,000; 3 Years

Nitrogen cycling is the conversion of this element between different chemical species and is the primary process affecting the amounts of this key plant nutrient in soil. A critical step in the nitrogen cycle is the transformation (oxidation) of ammonium to nitrite, a conversion that greatly increases the potential for nitrogen to be lost from soil. These losses diminish agronomic productivity, increase costs of crop production, and can result in the pollution of both air and water. As such, there is much interest in controlling this process, which is brought about by a specialized group of organisms, the ammonia oxidizing bacteria (AOB). Although AOB play a critical role in soil little is known about how they adapt to survive the stresses inherent to this environment. In this project, we will investigate these stress responses with a representative AOB, *Nitrosomonas europaea,* which is one of the few bacteria for which the entire genetic makeup (genome) has been determined. By knowing the genome of *N. europaea* we can predict all of the proteins that it could form (the proteome), and can identify the subset of the proteome produced when the organism is subjected to stresses that it would endure in soil. Determining the proteins comprising the stress response systems will allow us to map molecular networks that the AOB rely on to live in soil, and possibly to identify parts of these networks that might be used as molecular switches to regulate their activity.

2001-01201 Controls of C Sequestration on Northern Rocky Mountain Rangelands

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Grant 2001-35107-11327; $180,000; 2 Years

Understanding factors governing soil C sequestration are essential for addressing questions related to rising atmospheric CO_2 concentrations, global warming and ecosystem C exchange. Carbon sequestration is the net effect of C fixation by plants, heterotrophic respiration and production (microbial and plant), and soil C storage, all of which are potentially sensitive to land use, abiotic and biotic conditions, soil N processes and grazing. We will address the temporal coupling of soil N processes (N mineralization, immobilization) with net CO_2 exchange and long-term soil C storage, and grazing effects on microbial biomass production, N mineralization, SOM traits (labile vs. recalcitrant soil C) and annual budgets of net CO_2 exchange. We will compare C and N processes in grazed and ungrazed, fenced exclosures (ungrazed by domestic livestock for 60 years) primarily within a mixed-grass prairie, and secondarily in alpine grassland, forest meadow, and sagebrush shrubland grasslands, which combined represent over 50% of western U.S. grazed lands. Our studies will involve extensive comparisons of vegetation C and N characteristics (species composition, biomass production, photosynthesis, respiration), soil organic matter chemistry (constituents, pools), and biotic processes (microbial biomass, N mineralization) between the grazed and exclosure areas. In addition, we will quantify the magnitude of net CO_2 exchange in summer and winter using annual CO_2-C budgets as an estimate of current C sequestration patterns. Our project will advance the fundamental understanding of soil biological processes, especially the synchrony between soil N dynamics and CO_2 flux, while providing insight as to how land management may alter soil C sequestration.

2001-00594 Scale-Dependency and Spatial Variability of Soil Hydraulic Properties
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Soil water is the driving force for agricultural contaminant and nutrient transport in soils. Soil hydraulic properties are the key information needed to quantitatively describe water flow and chemical transport in soils and groundwater systems. However, hydraulic properties of natural soils are scale-dependent and spatially variable. The scale-dependency, variability, and heterogeneity of soil properties and their impact on transport processes in soils are poorly understood. The main objective of this sabbatical project is to measure soil hydraulic properties at different locations and different scales in large fields. The future research goals after the sabbatical are to develop scale-dependent relationships of soil hydraulic properties, and to characterize spatial variability and heterogeneity of soil hydraulic properties as a function of measurement scales and their impacts on transport processes in heterogeneous soils. The main objective on the sabbatical leave will be accomplished in the National Agriculture Experiment Station of China Agriculture University. It is the key component and starting point of the long-term goals to measure soil hydraulic properties at different locations and scales in large fields. However, it would be very time consuming and costly to collect such data. We will collect the data in China by taking the advantages of the well-equipped experiment station and much less expensive labor there. With the available research space, equipment, facilities, and manpower provided by the university, the proposed project will be conducted in the most economic and efficient way. In addition, the benefits from the international cooperation will be extremely valuable. After the sabbatical, I will analyze the hydraulic property data and develop theory, methodology, and applied models. This fundamentally important project will provide the essential information for solving problems of sustainable agriculture and the environment, such as to protect water resources from nonpoint source pollutants, improve soil and water quality, and enhance agricultural productivity.